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SECTION OF BIOLOGICAL AND MEDICAL SCIENCES

SPECIFIC DEVELOPMENTAL DISORDERS OF SPEECH AND LANGUAGE

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Abstract

Speech delay is a delay in the acquisition of verbal language in children compared to the age norm. Speech delay is characterized by a qualitative and quantitative underdevelopment of vocabulary, an underdeveloped expressive speech, and the absence of phrasal speech by age 2 and coherent speech by age 3. Specific speech and language development disorders are persistent difficulties in developing oral and/or written language that occur in children with normal hearing, intelligence, and articulatory abilities. They manifest themselves in delayed speech onset, a limited vocabulary, and grammatical errors (alalia, general speech underdevelopment). Disorders in which the normal acquisition of language skills is impaired early in development. These conditions are not directly related to neurological or speech impairments, sensory impairments, intellectual disability, or environmental factors. Specific speech and language disorders are often accompanied by related problems, such as difficulties with reading, spelling, and pronunciation, interpersonal dysfunction, and emotional and behavioral disorders.

Keywords: specificity, disorder, development, speech, language, late, speaking, writing, words, acquiring, difficulties, diagnostics, reading, speed, neurology, speech therapy, psychology.

INTRODUCTION AND PURPOSE:

Typically, all specific speech development disorders begin to manifest in childhood. The child uses sounds below the level appropriate for their mental age, but still has a normal level of speech skills. At the same time, the child has normal hearing, adequate mental development, a properly developed articulatory apparatus, and normal language skills. At the same time, children begin to speak late (their first words may not appear until age 2). Lexical language development deficits develop (they learn words poorly), and difficulty comprehending long sentences (especially at a fast pace) manifests itself, so children themselves often express themselves in short sentences. Reading and writing difficulties occur during school preparation. The main causes of the manifestation of symptoms in the so-called risk group can be pre-natal causes, birth trauma, hyperactive children, behavioral disorders, and frequently ill children. The goals of studying the medical and psychological aspects of speech delays in children are aimed at early identification of causes, a comprehensive assessment of higher mental functions, the development of individualized intervention programs, and the prevention of persistent developmental disorders. This allows for the integration of medical interventions (neurology) with psychological interventions (development of speech, attention, and memory).

METHOD: Literature analysis, personal observations and comparative analysis were used in the study.

RESEARCH:

This condition may be associated with dysfunctions of multiple organ systems, particularly the central nervous system (CNS) and the orofacial musculature. A correct diagnosis usually requires multidisciplinary approach such as a neurologist, logopedist, psychologist, and osteopath. Typically, such patients are referred to an osteopath after comprehensive clinical evaluation. If necessary, the doctor will prescribe instrumental and laboratory diagnostic investigations, including neuroimaging and neurological assessment. The primary clinical manifestations include delayed speech and language development (speech delay) and articulatory disorders, characterized by distorted or substituted phonemes. According to statistics, the prevalence of the disorder is approximately 10% among children under 8 years of age and approximately 5% among those over 8 years of age, with boys being affected 2-3 times more often than girls [2;4;6;11].

Prenatal etiologies include genetic abnormalities, intrauterine infections, chronic maternal diseases, micronutrient deficiencies, psychosocial stress, and exposure to environmental toxins. They operate from conception until parturition, affecting fetal neurodevelopment. The main factors are maternal age, lack of preconception care, obesity, and gestational or chronic hypertension. Speech disorders associated with perinatal and birth trauma are frequently linked to perinatal hypoxia-ischemia, traumatic brain injury, or cranial nerve compression, resulting in neurodevelopmental delay, paresis of the articulatory muscles, and functional impairment of cortical speech centers, including Broca's and Wernicke's areas.

FINDINGS:

The main symptoms include delayed speech and language development, dysarthric (slurred) articulation, impaired attention and concentration, and emotional lability. Early therapeutic intervention (from age 2) helps compensate for these impairments. Speech disorders associated with hyperactivity disorder (ADHD) in children are caused by accelerated

cognitive processing and attention deficits, manifesting as tachylalia (accelerated speech), impulsive or explosive speech, and breathing and articulation problems. Developmental delays, slurring, and syllable omission are also common, as are difficulties in verbal formulation and pragmatic communication. Speech impairments in behavioral disorders often manifest as dysarthria (impaired articulation and intonation), aphasia (difficulty understanding/producing speech), and echolalia (automatic repetition). Characteristics include monotonic prosody, flattened affect, learning difficulties, impulsivity, and deficits in social interaction. Frequent illnesses (especially viral infections and acute respiratory viral infections) in children weaken the body, leading to delayed speech ontogenesis (dysphonia, a weak, hoarse voice) and delayed development of all speech components. Constant oral breathing secondary to adenoid hypertrophy often causes speech impediments. Consultation with a pediatric ENT specialist and speech therapist is required [3;7;9;11].

A diagnosis of speech delay is usually given to children under 5-6 years of age, when there is hope for the natural development of the systems that slow the maturation of the psyche and speech function. The delay can manifest as delayed speech development, partial speech loss, or complete speech absence. This article discusses the main causes, signs, and types of speech delays in children. Speech delays associated with functional disorders arise from unfavorable upbringing conditions (pedagogical neglect) and severe somatic illnesses that impede the child's normal socialization and education, but are not associated with a disorder of the central nervous system. Often, these problems are caused not so much by anatomical factors as by psychological and social factors.

Speech development delay of organic etiology results from structural damage to the central nervous system (CNS). This can result from impaired functioning of partially damaged neural structures or functionally interconnected cortical and subcortical regions, i.e., from brain injury. There are two types of such delays:

Alalia. A complete or partial absence of speech with normal hearing and intellectual development. The child understands speech but does not speak or uses a limited set of words. This is due to organic damage to the speech areas of the brain, which makes it difficult to develop or understand speech.

Dysarthria. Problems with pronouncing sounds due to insufficient innervation (nerve conduction) of the muscles involved in speech, such as the tongue and lips. The child may have unclear, slurred speech and difficulty pronouncing sounds that require fine coordination. This occurs with damage to the central nervous system.

During the first consultation, an osteopathic physician looks for the cause of the disorder in the body, performing a visual examination and special manual tests [7;10].

Biological causes of speech delays: central nervous system pathologies such as cerebral palsy, brain injuries, encephalitis, and other injuries sustained in infancy and early childhood-that affect the motor skills necessary for pronouncing sounds and phrases. Hearing or vision impairments. Difficulties in perceiving and processing speech can cause delays. Mental retardation. Children with mental retardation have difficulty acquiring and applying speech skills. Severe somatic illnesses that interfere with normal socialization and education, but are not related to a disorder of the central nervous system: for example, severe heart defects-the child is prohibited from any physical activity and attending children's educational institutions, which severely limits their social circle [9;11].

Birth injuries, prematurity, and infections acquired during the prenatal period. Psychological etiologies: unfavorable psychological environment in the family-speech problems in a child can arise due to stress and anxiety. Lack of interaction with peers. Lack of adequate verbal stimulation from adults. Isolation and associated social deprivation (unmet need for communication). **Socioeconomic factors** also play a significant role. Children from disadvantaged families may have limited access to education, which can lead to delayed speech development. It is important to note that the causes of delayed speech development in children can be complex and involve several factors.

Speech developmental impairments restrict the child's interactions with peers and adults. This can lead to communication anxiety, avoidant behavior, and impaired socialization, so it is important to begin psychotherapeutic interventions as early as possible. The physician identifies the problem, functional restrictions, such as hypomobility and restricted range of motion in the musculoskeletal system, including joints. There can be many causes. People with identical symptoms may have completely different problems. Each osteopathic technique is individually tailored, depending on the patient's age, somatic characteristics, and specific functional impairments. Osteopathic techniques involve articulation work with the articular apparatus (joint work). These techniques primarily involve myofascial release (working with the fascia-the connective tissue covering the muscles-using the physician's hand movements, which leads to tissue relaxation), followed by muscle-energy techniques (the patient is asked to move and rotate according to the physician's prescribed algorithm). These improve regional blood circulation, enhance oxygen and nutrient delivery, facilitate metabolic waste removal, and normalize tissue biomechanics. One osteopathic session lasts from 30 minutes to an hour, and is performed every 10-14 days. The number of sessions is determined individually with the doctor; on average, 5-10 procedures with varying frequency are sufficient [4;5].

Regular preventive examinations with a pediatrician will help in early detection of potential risks of speech development disorders. Equally important is a critical assessment by parents or caregivers regarding speech development disorders. It is especially important to promptly identify and begin treatment for persistent auditory impairments (for example, those resulting from otitis media with effusion) before they negatively impact speech development. Speech development, an integral part of a child's overall development, will only benefit from active and attentive parental attention. Adults unconsciously adapt to the child's

needs and structure their speech with short, simple sentences, repeating or emphasizing important information several times [5;9].

The causes of speech development disorders, such as auditory impairments, should be addressed as quickly as possible. Speech development therapy is conducted individually, often through corrective and therapeutic exercises, which are most often performed by speech therapists. When speech disorders coexist with other neurodevelopmental or developmental impairments, an integrated, multidisciplinary intervention strategy is required [6;10].

It is crucial to promptly implement the treatment and preventative measures recommended by the pediatric clinic. Currently, there are many pharmacological agents available that promote the accelerated maturation of certain brain structures and normalize existing pathological processes. Nevertheless, speech therapists are essential for children's speech development.

RESULTS:

Today, we are witnessing the active implementation of innovative medical and psychological approaches to the correction of speech disorders in early childhood. One of the most promising directions is the application of information and communication technologies (ICT), including specialized software platforms and educational gaming applications, designed to automate articulatory patterns, enhance phonemic awareness, and facilitate the development of lexical and grammatical competencies. Telemedicine, providing access to speech therapy through remote consultations and sessions, is also becoming widespread. The bioacoustic correction method is an innovative approach based on the use of acoustic stimuli modulated according to individual electroencephalogram parameters, with the aim of normalizing the functional state of the brain and optimizing speech processes. Thus, early speech therapy intervention is an effective and essential means of preventing and correcting speech disorders in young children. The use of modern diagnostic and intervention methods based on the principles of integrative and activity-based approaches, as well as the active involvement of families in the intervention process, enables significant results and ensures the full development of each child. Speech therapists play a central role in the early intervention system, providing diagnostic, interventional, consulting, educational, and scientific and methodological support. Investments in early intervention are investments in the future of each child and society as a whole.

In modern speech therapy practice, a wide range of methods and techniques are used to correct speech disorders in young children, designed to optimize speech apparatus function and develop speech competencies. Traditional and widely used methods include: articulatory exercises, aimed at developing the mobility and coordination of the muscles of the articulatory apparatus; speech therapy massage, which improves muscle tone and circulation in this area; exercises for developing phonemic hearing, which promote the ability to distinguish and analyze speech sounds; techniques for developing the lexical and grammatical structure of speech, including games and exercises to enrich vocabulary and master grammar; and sensory integration methods, which stimulate and harmonize the interaction of the visual, auditory, tactile, and proprioceptive systems.

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SECTION OF EARTH SCIENCES

HUMAN METEOROTROPIC REACTIONS IN RESPONSE TO SLIGHT FLUCTUATIONS IN ATMOSPHERIC PRESSURE

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Abstract
The amplitude of low-frequency atmospheric pressure fluctuations was monitored, and the diurnal and seasonal dynamics of the APF were investigated, along with their correlations with other meteorological parameters. Correlations were also identified between the physical parameters of the APF and the frequency of emergency transport cases for cardiovascular diseases, sports injuries and suicide-related injuries during the monitoring period. It was established that the amplitudes of atmospheric pressure fluctuations have safe, risky, unfavourable and favourable ranges of influence on the frequency of emergency transport cases during APF with periods of 3–120 s. A comparison was also made of the influence of APF during periods of 120–1200 s on human meteorotropic reactions.

Keywords: weather; atmospheric pressure fluctuations**;** meteorotropic reactions**;** emergency transport events.

INTRODUCTION

Weather forecast is very important for the prevention of negative effects of weather factors on people health. According to numerous medico-meteorological studies the main significant meteorotropic parameters are air temperature, humidity, barometric pressure and wind velocity. Weather services provide the reliable information on these classical meteorological parameters on different time-scales all over the world. However, very little attention is paid to the effects on people of other non-classical meteorological parameters.

Recently, meteorotropic properties have been attributed to the slight atmospheric pressure fluctuations (APF) with second, minute and decaminute periods, related to the far-infrasound ($0.003\ Hz < f < 1\ Hz$) and internal gravity waves (from one minute and more) ranges [1-3]. Such APF are considered as natural noise in the atmosphere, originating from very different source. The most widespread and strong source of APF is chaotic turbulent noise of airflows [4,5].

The possible adverse effects of high levels of APF on human psycho-physiological, autonomic and vestibular functions were suggested by experimental studies with artificial oscillations of barometric pressure in the far infrasound frequency range. The paper [6] reports on autonomic and vestibular disorders in a group of subjects exposed to barometric pressure oscillations in special chamber (from 0.4 mm Hg (~50 Pa) to 4 mmHg (~500 Pa) with period characteristics of the far infrasound range (about 4 s)). The data presented the increase in number of mistakes during attention task performance, as well the deterioration of stato-kinetic ability. The changes in indices of mental activity, and autonomic reactions under extra-low-frequency pressure oscillations, modeling natural characteristics of APF, were observed in a group of subjects [7].

It have been suggested that heightened anxiety levels in people with mental disorders, as well the increase in incidence of suicides and occurrences of cardiac arrhythmias during episodes of strong wind could be at least partly due to biological response to ultra-low-frequency pressure fluctuations created by wind induced turbulence [6,8,9]

Our experimental studies with animals, as well as studies of other authors in otolaryngology, suggest that special baroreceptors of APF exist in human body [10]. We found the biomechanical reactions of a certain part of the tympanic membrane (pars flaccida) in response to slight oscillations of air pressure in the far infrasound frequency range in the middle ear. The obtained data point out that the pars flaccida is capable of tracing the natural levels of APF, at least, from a few Pa and may be even from fractions of a Pa up to hundreds of Pa. Some studies suggest that there is a pathway, through which changes in the pressure are transmitted from the middle ear to the inner ear otolithic receptors [11,12], which in their turn mediate the vestibulo-sympathetic reflex [13]. Clinical observations suggested that high levels of APF had adverse effects on patients with rheumatic, cerebro- and cardiovascular diseases, as well disorders in the central nervous system [14]. A correlation between strong natural infrasonic waves and automobile accidents, as well as schoolchildren behavioral demonstrations of being unwell has been shown [15].

The important feature of APF is that they penetrate buildings and therefore could be responsible for weather sensitivity symptoms indoors, as well as outdoors. The potential risk of APF for people health is aggravated by the fact, that people cannot feel them and standard methods and means for their measurements are not available.

METHODS OF ANALYSIS

Long-term monitoring of atmospheric pressure was conducted in Kyiv, and the diurnal and seasonal variations in atmospheric pressure, as well as their relationships with other meteorological parameters, were studied. Correlations were also identified between the physical parameters of the APF and the incidence of emergency transport due to cardiovascular diseases, sports injuries, and suicide-related injuries in Kyiv during the monitoring period.

Atmospheric pressure was monitored in Kyiv over the course of one year—from July 1, 2015, to June 30, 2016. The study was conducted outdoors using a microbarometer. For these we used high sensitive (1 Pa) microbarometer with high temporal resolution (measuring rate 2 Hz) and specially developed computer program for calculation and visualization of APF spectral parameters.

The value of atmospheric pressure was recorded every 0.5 s. A special computer program, developed by us, was used to calculate the average integral amplitude of APF over each hour of the day in two ranges of their periods: 3 s - 120 s (second-minute periods) and 120 s - 1200 s (minute-decaminute periods). The first range was selected taking into consideration the results of our previous experimental investigations of biological effects of atmospheric pressure oscillations with periods in the range of far infrasound [6,16]. We are not aware of any studies that support the hypothesis that natural AFTs with periods extending beyond the range of acoustic phenomena are capable of influencing the human body and behaviour. The second range of APF periods with prevailing minute and decaminute waves of non-acoustical origins was selected to verify these suggestions. According to identification of frequency ranges accepted in the physics of atmosphere, APF were related primarily to infrasonic phenomenon in the first range, and to internal gravity waves in the second range.

Three-hourly meteorological data (temperature, relative humidity, wind velocity and atmospheric pressure) were obtained from Kyiv Geophysical Observatory for the same 1-year period.

Daily number of emergency transport events on circulatory system diseases (EEC) by International Classification of Diseases, 10th Revision (I00-99) and sport (EESP) and suicidal (EESU) injuries for the same year period were obtained from the Kyiv Station of emergency services and medicine of catastrophes.

The mean daily amplitude of APF in two frequency ranges identified above was used for the analysis of relation with EEC, EESP and EESU. We used the mean daily values of temperature, relative humidity, wind velocity and atmospheric pressure to analyze the possible role of these classical meteorological parameters as confounding factors. We controlled the season and day of week effects, and allowed for the annual trend in EE to control the effects of slow-time varying environmental factors. All public holidays were excluded from the data.

Polynomial approximation was used to assess visually the functional character of the relation of EEC, EESP and EESU to increase in value of APF amplitude. We applied regression models to compare groups [17] for exploring the relationships between emergency transport events and independent atmospheric variables.

As dependency of emergency transport events on atmospheric variables may be non linear, the non-parametric smoothing method was chosen. We used the Loess technique to eliminate the confounding variables pattern in the data of emergency transport events in a stepwise manner.

The atmospheric variables, as well the number of emergency transport events, except for the EEC, were not normally distributed. Therefore, respectively the non-parametric (Mann-Whitney U-test and Sherman rank correlation test) and parametric (Tukey HCD) estimation were applied. Statistical analysis was performed with Matlab 6.6 (Curve Fitting Toolbox), Statistica 6 and MS Excell.

RESULTS

During APF monitoring, daily graphs of atmospheric pressure variations were obtained. Fig. 1 shows the daily dynamics of the deviation of atmospheric pressure from the mean value and the APF in two ranges of their periods: from 120 s to 1200 s and from 3 s to 120 s for two different days (the upper and lower parts of the fig.1).

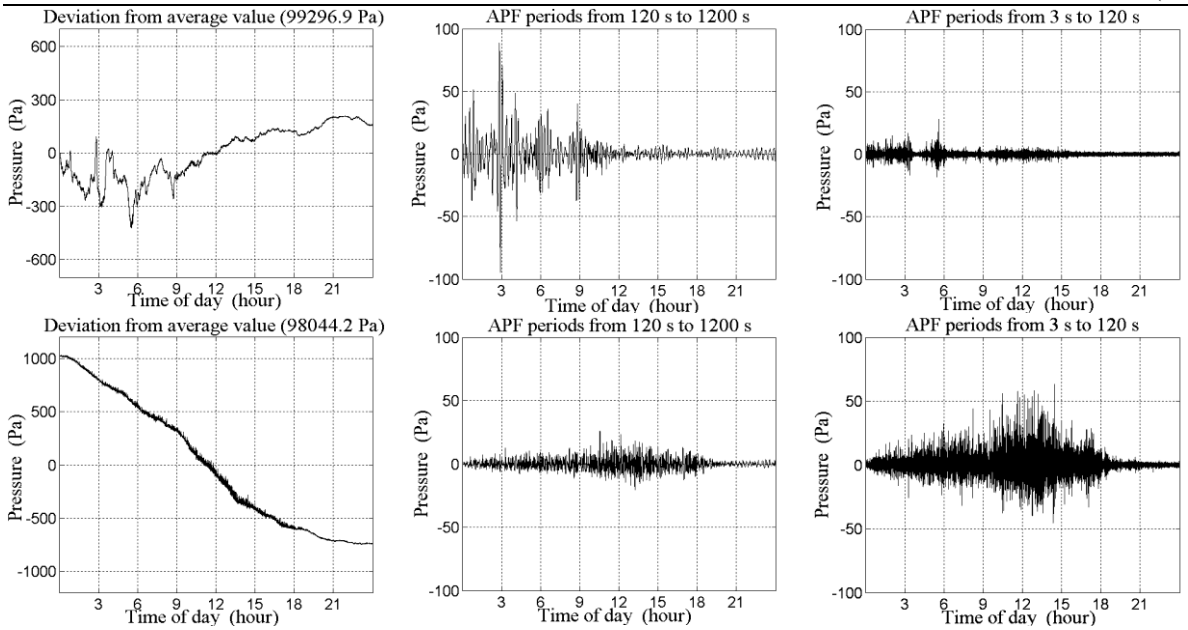
Deviation from average value (99296.9 Pa)
APF periods from 120 s to 1200 s
APF periods from 3 s to 120 s
Deviation from average value (98044.2 Pa)
APF periods from 120 s to 1200 s
APF periods from 3 s to 120 s
Pressure (Pa)
Time of day (hour)

Fig. 1 The daily dynamics of atmospheric pressure deviation from the average value and APF with periods: from 120 s to 1200 s (related mainly to non acoustical phenomenon – internal gravity waves) from 3 s to 120 s (related mainly to far infrasound phenomenon) for two different days. High APF amplitude levels were recorded at different times of the day on different days (upper and lower parts of fig. 1).

It should be noted that the annual average daily variation in the 1-hour average integral amplitude of the APF exhibited a distinct wave-like pattern in the first and second frequency ranges (Fig. 2). However, the average range of the APF varies between the autumn–winter and spring–summer seasons.

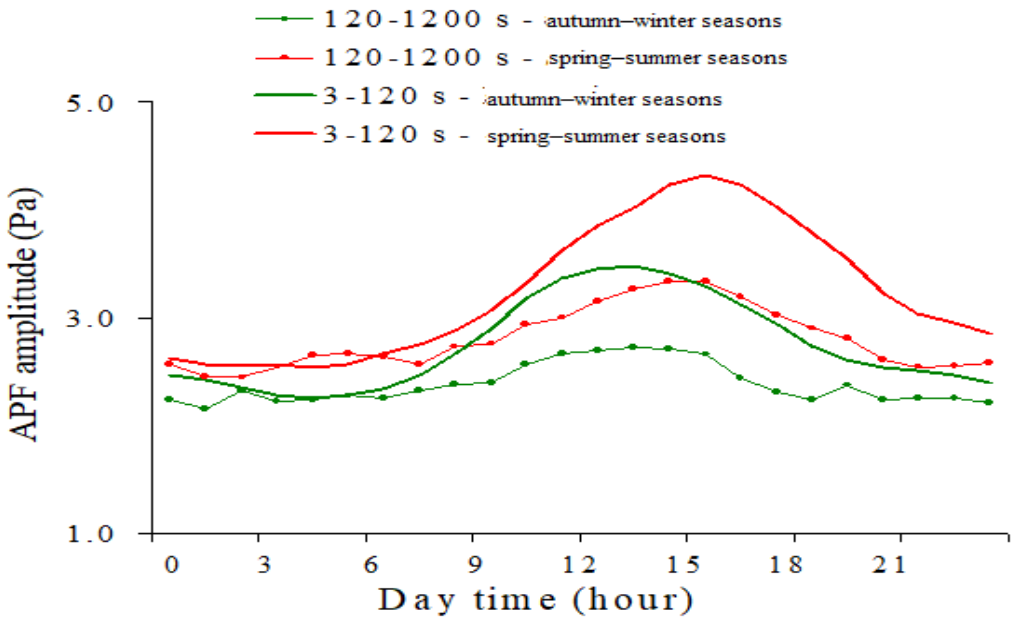
120-1200 s - autumn–winter seasons
120-1200 s - spring–summer seasons
3-120 s - autumn–winter seasons
3-120 s - spring–summer seasons
APF amplitude (Pa)
Day time (hour)

Fig. 2 Daily variations in the average integral amplitude of atmospheric pressure fluctuations (APF) with periods ranging from 120 s to 1200 s and from 3 s to 120 s over a one-hour period during different seasons, averaged over the year.

The amplitude of APF was increasing in the first semi-wave from night to day, followed by a decrease in the other semi-wave from day to night. This shape was similar to such of classical meteorological parameters as temperature, wind velocity and inverse to relative humidity.

The year dynamics of APF amplitude revealed pronounced correlation:

- with wind velocity: for APF with periods 3 s – 120 s - **r = 0.72**,

for APF with periods 120 s - 1200 s - **r = 0.49**, p < 0.00001;

-with temperature: : for APF with periods 3 s – 120 s - **r = - 0.38**,

for APF with periods 120 s - 1200 s - **r = - 0.27**, p < 0.00001.

We also tested the relations between physical parameters of APF and rate of emergency transport events due to circulation systems diseases, sport and suicide injuries. Unfavorable for people health were high mean

daily values of APF in the far infrasound range (3 s – 120 s), as well the high ratio of the APF values during the nighttime to those during the daytime. We found non-linear relation between all selected kinds of emergency transport events and amplitude of APF in the far infrasound range (AI) (Fig. 3). The number of emergency transport events increased significantly at the boundary between two categories of values of the APF amplitude: their high and middle-low values, pointing to threshold effects of APF.

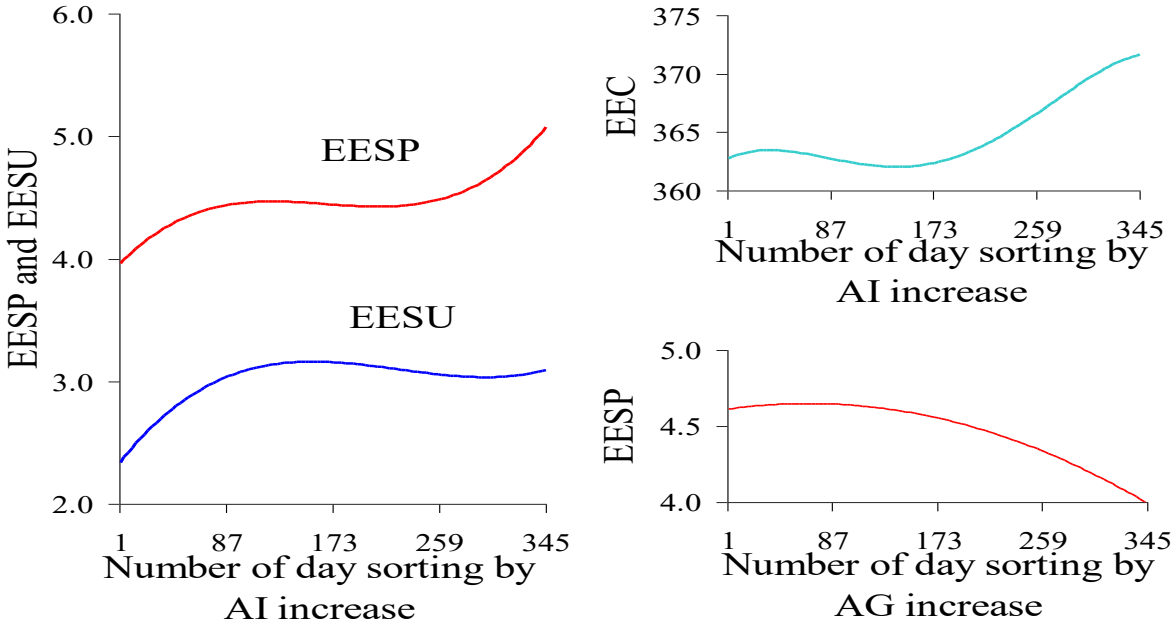

Fig. 3 Daily number of emergency transport events coded as sport injuries (EESP), suicidal injuries (EESU) and circulatory system diseases (EEC) plotted against the number of days of the year, sorting by increase in mean daily integral amplitude of atmospheric pressure fluctuations with periods 3 s – 120 s (AI) and 120 s - 1200 s (AG)

We did not found the adverse effects on people with health problems of the APF in the range of longer periods (120 s – 1200 s). The number of EEC and EESP was significantly greater for days with high APF amplitude in this frequency range versus the days with low and middle levels of such APF. The threshold of APF levels for the increase in EESU was lower than those for the EEC and EESP, suggesting greater sensitivity of people with suicidal tendency to this atmospheric factor (tabl. 1). This is discussed in more detail in table 1.

Table 1 presents the values of the confidence intervals (CI: - 95% - + 95%) for: safety and risky range of amplitude of atmospheric pressure fluctuations (APF) with periods: 3 s – 120 s (AI) (related mainly to the far infrasound phenomenon); unfavorable and favorable range of amplitude of APF with periods, as well as for the unfavorable and favorable APF amplitude ranges with periods of 120 s to 1200 s (AG) (associated primarily with internal gravitational waves).

Table 1.

Safe and risky ranges of atmospheric pressure fluctuation amplitude (APF) with different periods.

N	Data	(CI: - 95% - + 95%)	(CI: - 95% - + 95%)	P
APF with periods 3 s – 120 s (AI) **Safety amplitudes of APF Risky amplitudes of APF**				
	APF amplitude	**1.8 – 2.0 (Pa)**	**5.1 – 5.9 (Pa)**	
1	**EEC** number	358.0 – 365.6 (n_1 = 260)	366.8 – 381.0 (n_2 = 87)	$p < 0,01$
2	**EESP** number	4.1 - 4.6 (n_1 = 254)	366.8 – 381.0 (n_2 = 87)	$p < 0,032$
	APF amplitude	**1.1– 1.2 (Pa)**	**3.2 – 3.6 (Pa)**	
3	**EESU** number	2.4 – 3.1 (n_1 = 85)	2.9 - 3.3 (n_2 = 260)	$p < 0,044$
APF with periods 120 s – 1200 s (AG) **Unfavorable amplitudes of APF Favorable amplitudes of APF**				
	APF amplitude	**1.7 – 1.8 (Pa)**	**3.2 - 3.6 (Pa)**	
4	**EESP** number	4.4 – 4.9 (n_1 = 214)	3.8 – 4.5 (n_2= 131)	$p < 0,011$

n_1,n_2 – number of days emergency transport cases for two ranges of AF amplitude;
P - significance of the difference in number of emergency transport events.

The daily numbers of emergency transport cases (n_1, n_2) related to cardiovascular diseases (EEC), sports injuries (EESP) and suicide-related injuries (EESU) are also presented, adjusted for variables that may introduce bias, for two ranges of AF amplitude.

DISCUSSION

We did not find the adverse effects of high amplitudes of the *APF in the range of periods attributed mostly to the internal gravity waves phenomenon* (fig. 3). Moreover, the obtained results (table. 1) point that their high values could be considered as activating factor promoting successful adaptation to sport activity and decrease in number of sport injuries.

According to our findings, even middle levels of APF dominating in common atmospheric condition can aggravate psychiatric disorders such as suicidal ideation. Unfavorable for the increase in EEC was also the low ratio of APF amplitude in the far infrasound range during the daytime to those during the nighttime.

The value of deviation of daily dynamics of APF in the far infrasound range from their normal daily shape towards increase in the nightly levels of APF relatively to their daily levels turn out to be the biologically important parameter. The obtained results suggest that low ratio of APF amplitude during the daytime to those during the nighttime (less than 1. 5) can promote deterioration of ischaemic heart and hypertensive diseases. In contrast, the normal APF daily dynamics (with lower values at night and higher values during the day) seems to coincide with environmental characteristics promoting the circadian rhythm of circulatory physiological and biochemical processes. Particularly, such daily shape is demonstrated by autonomic shift from parasympathetic predominance at night to sympathetic prevailing drive in the day. Therefore, it can be speculated that decrease in APF amplitude at night and increase at day could cause domination of parasympathetic influences during sleeping and sympathetic influences during the day activity, promoting autonomic circadian rhythms. From this point of view the normal daily dynamics of APF can be considered as a beneficial environmental condition, especially for people with circadian disorders in circulatory functions.

Our previous experimental investigations of the effects of artificial atmospheric pressure oscillations in the far infrasound frequency ranges on mental, autonomic and biomechanical reactions, as well the present study suggest the important role of APF as a potentially risky meteorological factor for people health and environment safety, e.g. in traffic or at the workplace. From this point of view the systematic monitoring and forecasting of APF bioeffective physical parameters could be considered as actual task for weather services.

CONCLUSIONS

1. Studies into the effects of artificial fluctuations in atmospheric pressure within the far-infrasound frequency range on psychological, autonomic and biomechanical responses indicate that APF plays an important role as a potentially hazardous meteorological factor for human health and environmental safety, for example in road traffic or in the workplace.

2. The results of the study indicate that high-amplitude APF, predominantly in the far-infrasound frequency range, has a meteorological effect, acting as a risk factor that contributes to the worsening of cardiovascular diseases and an increase in the incidence of sports injuries.

3. Continued monitoring of the physical parameters of the APF is of particular importance for gathering new data and advancing scientific research in the field of biomedical meteorology.

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SECTION OF HUMANITIES AND PHILOLOGY

CROSS-CULTURAL AND GLOBAL LITERARY TRENDS

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Abstract

This article examines the evolution of cross-cultural and global literary trends in the context of globalization, migration, and technological transformation. It explores how literature transcends national and linguistic boundaries through translation, digital media, and intercultural exchange. The study analyzes key literary works and authors representing hybrid identities, demonstrating how global literature reflects diverse cultural perspectives while addressing universal human experiences. Particular attention is given to the role of translation in reshaping meaning, the impact of diaspora writing on identity formation, and the influence of digital platforms in democratizing literary production. The article also discusses how contemporary writers blend multiple literary traditions, challenge canonical structures, and redefine concepts of authorship and readership. Through examples from African, Latin American, Asian, and European literature, the study highlights the emergence of a dynamic and interconnected literary space. It argues that global literary trends promote inclusivity, diversity, and cultural dialogue, while also raising critical questions about power, representation, and authenticity. Ultimately, the research demonstrates that cross-cultural literature plays a crucial role in fostering global understanding and shaping modern literary discourse in an increasingly interconnected world.

Keywords: cross-cultural literature, globalization, literary trends, hybridity, cultural identity.

The development of cross-cultural and global literary trends is closely connected with the processes of globalization, cultural exchange, and technological advancement. In the contemporary world, literature is no longer confined within national or linguistic borders, but instead circulates widely across different cultural contexts, allowing readers to engage with diverse perspectives and experiences. One of the clearest examples of this phenomenon is the global recognition of Chinua Achebe's novel Things Fall Apart, which has been translated into more than 50 languages and is widely studied across the world. This demonstrates how a text rooted in a specific African context can become part of global literary discourse. Similarly, Haruki Murakami has achieved international popularity, with novels such as Norwegian Wood resonating with readers across cultures due to their universal themes of loneliness and identity. These examples illustrate that global literature often balances cultural specificity with universal relevance. Furthermore, the rise of international literary prizes, such as the Nobel Prize in Literature, has contributed to the global recognition of diverse voices. Writers from different cultural backgrounds are now able to reach global audiences, challenging the dominance of Western literary traditions. As a result, literature becomes a space where cultural boundaries are negotiated and redefined [1].

The role of translation in shaping global literary trends cannot be overstated, as it serves as a crucial bridge between cultures and languages. Translation allows literary works to transcend linguistic barriers, making them accessible to a wider audience and facilitating intercultural dialogue. A significant example is One Hundred Years of Solitude by Gabriel García Márquez, which gained international acclaim largely due to its English translation. The novel introduced magical realism to global audiences and influenced writers worldwide. Similarly, Fyodor Dostoevsky's works, including Crime and Punishment, have reached readers globally through translation, shaping philosophical and psychological literary traditions beyond Russia. However, translation is not merely a linguistic process; it involves cultural interpretation. Scholars such as Lawrence Venuti argue that translation can either domesticate or foreignize a text, influencing how it is perceived by readers [2]. This highlights the power of translation in shaping global literary reception and meaning.

Migration and diaspora have also played a significant role in the development of cross-cultural literary trends, as they have led to the emergence of hybrid identities and narratives. Writers such as Salman Rushdie, particularly in Midnight's Children, explore postcolonial identity and the complexities of cultural belonging. Similarly, Jhumpa Lahiri's Interpreter of Maladies reflects the experiences of immigrants navigating between cultures. These works highlight the emotional and psychological dimensions of displacement, memory, and adaptation. Diasporic literature often challenges fixed notions of identity, presenting it as fluid and multifaceted. Moreover, such texts contribute to global literary diversity by incorporating multiple cultural perspectives. They also reveal the social and political challenges faced by migrants, including discrimination and cultural alienation. Through these narratives, literature becomes a powerful tool for understanding the human impact of globalization [3].

Another important factor influencing global literary trends is the impact of digital technologies and media. The rise of online platforms has allowed authors to publish and distribute their work globally without relying solely on traditional publishing houses. For instance, platforms such as Wattpad have enabled millions of writers to share their stories with international audiences. Some works published online have even been adapted into films and printed books, demonstrating the growing influence of digital literature. Additionally, global phenomena such as Harry Potter series by J. K. Rowling illustrate how literature can achieve

worldwide popularity through digital media, translations, and film adaptations. These texts create global fan communities that transcend cultural boundaries. Digital technologies also encourage interactive storytelling and new literary forms, such as hypertext fiction. However, they raise questions about quality control and the commercialization of literature. Despite these concerns, digitalization continues to reshape how literature is created and consumed [4].

Cross-cultural literary trends also involve the reinterpretation of traditional narratives and the blending of different literary forms. Postcolonial writers often challenge dominant historical narratives by presenting alternative perspectives. For example, Wide Sargasso Sea by Jean Rhys reimagines the story of Bertha Mason from Jane Eyre, giving voice to a previously marginalized character. This intertextual approach highlights how literature can reinterpret and transform existing narratives. Similarly, Kazuo Ishiguro's The Remains of the Day reflects both British and Japanese cultural influences, illustrating the blending of traditions. These examples demonstrate how contemporary literature often transcends cultural boundaries, creating hybrid forms that reflect global realities. At the same time, they raise important questions about authenticity and representation. Writers must navigate the complexities of cultural exchange while respecting the integrity of different traditions [1].

Another important dimension of cross-cultural literary trends is their role in education and the development of intercultural competence. In modern educational systems, literature is increasingly used as a tool for teaching not only language skills but also cultural awareness and critical thinking. By engaging with texts from different cultural backgrounds, students develop the ability to interpret diverse perspectives and understand complex social realities. This is particularly relevant in the context of English language teaching, where literature serves as an authentic resource for language acquisition. Furthermore, cross-cultural literature supports the development of critical literacy by encouraging students to question stereotypes and dominant narratives. It allows educators to integrate language learning with cultural studies, creating a more holistic educational experience. As a result, literature becomes a bridge between language and culture, promoting deeper understanding and communication.

The globalization of literature is also closely linked to the expansion of international publishing markets and the influence of economic factors. Large publishing houses and literary agents play a significant role in determining which texts gain global visibility. Works that align with global market demands are more likely to be translated and distributed internationally, while others may remain confined to local contexts. This creates a complex relationship between artistic expression and commercial success. For example, the global popularity of certain genres, such as fantasy and young adult fiction, demonstrates how market trends influence literary production. At the same time, international book fairs and literary festivals provide platforms for cross-cultural exchange and collaboration. Events such as the Frankfurt Book Fair bring together authors, publishers, and readers from around the world, facilitating the circulation of ideas and texts. However, the dominance of certain languages, particularly English, raises concerns about linguistic inequality and cultural homogenization. Despite these challenges, the global publishing industry continues to expand, shaping the direction of contemporary literary trends.

The question of cultural identity and representation remains central to cross-cultural literary studies. As literature becomes increasingly globalized, authors face the challenge of representing their cultures in ways that are both authentic and accessible to international audiences. This often involves negotiating between local traditions and global expectations. Writers such as Elif Shafak and Orhan Pamuk exemplify this dynamic, as their works reflect both national identity and global themes. Their narratives explore issues such as memory, history, and cultural conflict, highlighting the complexity of identity in a globalized world. At the same time, cross-cultural literature challenges stereotypes and promotes more nuanced representations of different cultures. It encourages readers to move beyond simplistic or exoticized views and to engage with the diversity of human experience. However, the pressure to appeal to global audiences can sometimes lead to the simplification or commodification of cultural elements. Therefore, the balance between authenticity and accessibility remains a key concern in contemporary literary production.

Conclusion

In conclusion, cross-cultural and global literary trends represent a transformative shift in the way literature is created, disseminated, and interpreted in the modern world. The interaction between globalization, translation, migration, and digital innovation has produced a rich and diverse literary landscape that reflects the complexity of contemporary human experience. Through concrete literary examples, it becomes evident that literature has the capacity to transcend cultural boundaries while preserving the uniqueness of individual traditions. At the same time, the expansion of global literary networks has challenged traditional hierarchies and contributed to the diversification of the literary canon. However, these developments also raise important questions about power relations, cultural representation, and the influence of market forces. Issues such as linguistic dominance, cultural appropriation, and the commercialization of literature require careful critical consideration. Despite these challenges, cross-cultural literature continues to serve as a powerful medium for dialogue, understanding, and intellectual exchange. It enables readers to engage with multiple perspectives, fostering empathy and global awareness. Moreover, its role in education and cultural exchange highlights its broader social significance. As global interconnectedness continues to deepen, the importance of cross-cultural literary studies will increase, making it an essential field for future research. Ultimately, literature remains one of the most effective tools for bridging cultural divides and promoting a more inclusive and interconnected world.

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РОЛЬ БАЛЬНОГО ТАНЦЮ У ФІЗИЧНОМУ, ПСИХОЕМОЦІЙНОМУ ТА ЕСТЕТИЧНОМУ РОЗВИТКУ ДІТЕЙ ДОШКІЛЬНОГО ВІКУ

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THE ROLE OF BALLROOM DANCE IN THE PHYSICAL, PSYCHOEMOTIONAL, AND AESTHETIC DEVELOPMENT OF PRESCHOOL CHILDREN

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Анотація

У статті обґрунтовано роль бального танцю як ефективного засобу комплексного розвитку дітей дошкільного віку. Розкрито вплив танцювальної діяльності на фізичний стан, психоемоційну сферу та естетичне виховання дитини. Визначено педагогічні умови раннього навчання (3–6 років), зокрема принципи ігрової діяльності, наочності, доступності та емоційної насиченості. Доведено, що бальний танець сприяє розвитку координації, музикальності, соціальних навичок і творчого мислення, забезпечуючи гармонійне формування особистості.

Abstract

The article substantiates the role of ballroom dance as an effective means of comprehensive development of preschool children. It highlights the impact of dance activities on physical condition, psycho-emotional development, and aesthetic education. The pedagogical conditions for early training (ages 3–6) are defined, including principles of play-based learning, visualization, accessibility, and emotional engagement. It is proven that ballroom dance enhances coordination, musicality, social skills, and creative thinking, ensuring the harmonious development of a child's personality.

Ключові слова: бальний танець; дошкільний вік; фізичний розвиток; психоемоційний розвиток; естетичне виховання; рухова активність.

Keywords: ballroom dance; preschool age; physical development; psycho-emotional development; aesthetic education; motor activity.

Постановка проблеми. Рух є фундаментальною основою життєдіяльності людини. Потреба в русі виступає однією з базових біологічних і соціальних потреб, що забезпечує не лише фізичний розвиток організму, а й формування психічних процесів, емоційної сфери та особистісних якостей.

У дошкільному віці рухова активність відіграє визначальну роль, оскільки саме в цей період відбувається інтенсивне становлення всіх систем організму. Формуються основні рухові навички, розвивається координація, гнучкість, швидкість реакції, закладаються передумови до подальшого фізичного та інтелектуального розвитку.

Водночас сучасні соціокультурні умови характеризуються суттєвим зниженням рівня рухової активності дітей. Активне використання цифрових пристроїв, збільшення часу пасивного дозвілля, обмеження природної рухливості призводять до зростання кількості дітей із порушеннями постави, зниженням витривалості, проблемами опорно-рухового апарату та психоемоційними труднощами.

У цьому контексті особливої значущості набуває впровадження таких видів діяльності, які поєднують у собі фізичний розвиток, емоційне збагачення та естетичне виховання. Бальний танець є одним із найбільш ефективних засобів такого комплексного впливу.

Аналіз досліджень і публікацій. Проблема взаємозв'язку рухової активності та розвитку дитини має глибоке наукове підґрунтя. Дослідження Є. Аркіна доводять, що рух є ключовим фактором активізації інтелектуальної та емоційної діяльності. У працях А. Леонтьєва підкреслюється, що дошкільний вік є періодом первинного становлення особистості, коли закладаються основні риси характеру та поведінкові моделі.

Важливу роль у розвитку теорії музично-рухового виховання відіграли Е. Жак-Далькроз, К. Орф, С. Судзукі, М. Мартено. Їхні дослідження підтверджують ефективність інтеграції музики та руху як засобу розвитку музикальності, ритмічного відчуття та творчих здібностей.

У сучасній педагогічній науці значна увага приділяється комплексному підходу до розвитку дитини, який передбачає поєднання фізичних, емоційних і творчих компонентів. Однак проблема раннього залучення дітей до бального танцю (з 3 років) залишається недостатньо дослідженою, що визначає наукову новизну даної роботи.

Метою статті є комплексне обґрунтування ролі бального танцю як ефективного засобу фізичного, психоемоційного та естетичного розвитку дітей дошкільного віку, а також визначення педагогічних умов раннього навчання (з трирічного віку).

Виклад основного матеріалу.

Світ дитинства нерозривно пов'язаний із рухом. Дитина пізнає навколишній світ через активну взаємодію з ним, що реалізується насамперед через рухову діяльність. Рух виконує не лише фізіологічну функцію, а й виступає засобом розвитку мислення, мовлення, уяви та емоцій.

Систематична рухова активність сприяє:

- розвитку сенсомоторної координації;
- формуванню просторового мислення;
- активізації когнітивних процесів;
- зміцненню нервової системи.

Недостатність руху, навпаки, призводить до гальмування розвитку та появи функціональних порушень.

Бальний танець у сучасному науково-педагогічному дискурсі розглядається не лише як вид мистецтва чи спортивної діяльності, а як цілісна інтегрована педагогічна система, що забезпечує комплексний розвиток особистості дитини. Його специфіка полягає у синтезі різних видів діяльності: рухової, музичної, емоційної, комунікативної та творчої.

З позицій системного підходу бальний танець виконує одночасно кілька функцій:

- освітню (формування знань, умінь і навичок рухової діяльності);
- розвивальну (розвиток фізичних і психічних якостей);
- виховну (формування моральних і естетичних цінностей);
- соціалізуючу (інтеграція дитини в соціальне середовище).

Особливістю бального танцю є його здатність забезпечувати синергетичний ефект, коли взаємодія різних компонентів (музики, руху, емоції) підсилює загальний педагогічний результат.

Крім того, бальний танець можна розглядати як форму неформальної освіти, яка реалізується через діяльність, що відповідає віковим потребам дитини - грі, руху та емоційному переживанню.

З фізіологічної точки зору, бальний танець є ефективним засобом розвитку функціональних систем організму дитини. У дошкільному віці відбувається активне формування опорно-рухового апарату, нервової системи та координаційних механізмів.

Виконання танцювальних рухів сприяє:

- активізації роботи центральної нервової системи;
- формуванню стійких нейронних зв'язків між руховими та сенсорними центрами;
- розвитку пропріоцепції (відчуття положення тіла у просторі);
- удосконаленню міжм'язової координації.

Особливу роль відіграє координаційна складність танцювальних рухів, яка стимулює розвиток мозкових структур, відповідальних за планування та контроль рухів.

Регулярні заняття бальним танцем також позитивно впливають на: серцево-судинну систему (покращення кровообігу); дихальну систему (збільшення життєвої ємності легень); опорно-руховий апарат (зміцнення м'язового корсету, профілактика сколіозу).

Важливою перевагою є дозованість фізичного навантаження, що відповідає віковим можливостям дітей і сприяє гармонійному розвитку без ризику перенапруження.

З точки зору психології розвитку, танець є ефективним засобом формування емоційної компетентності дитини. У дошкільному віці емоції виступають провідним регулятором поведінки, тому діяльність, яка має емоційне наповнення, є найбільш результативною.

Танцювальна діяльність сприяє:

- розвитку емоційної чутливості;
- формуванню здатності до емпатії;
- усвідомленню власних емоцій і їх вираженню;
- розвитку саморегуляції.

Через рух дитина отримує можливість безпосереднього емоційного переживання, що є важливим механізмом психічного розвитку.

Згідно з діяльнісним підходом, емоційне включення у діяльність підвищує рівень засвоєння матеріалу. Саме тому танець, як емоційно насичена діяльність, є ефективним засобом навчання.

Крім того, танцювальна діяльність виконує функцію психологічного розвантаження, знижуючи рівень тривожності, агресії та напруження.

Музично-ритмічний компонент є базовим у структурі бального танцю. Взаємозв'язок музики та руху ґрунтується на психофізіологічних механізмах синхронізації слухових і моторних процесів.

Ритм виступає універсальним організуючим фактором, який:

- структурує рухову діяльність;
- формує відчуття часу;
- сприяє узгодженості рухів.

У процесі занять формується так званий ритмічний інтелект, який включає здатність:

- відчувати метроритмічну структуру;
- відтворювати ритмічні малюнки;
- імпровізувати в межах заданого ритму.

Згідно з теоріями музичного виховання (Е. Жак-Далькроз, К. Орф), поєднання руху і музики є найбільш ефективним способом розвитку музикальності у дітей.

Використання елементарних ритмічних вправ (кроки, плескання, рухи в такт) сприяє формуванню слухо-рухової координації, що є основою подальшого музичного розвитку.

Бальний танець є соціально орієнтованою діяльністю, оскільки передбачає взаємодію між партнерами та роботу в колективі. Це створює умови для формування соціальних компетентностей дитини.

У процесі занять формуються: навички комунікації, здатність до співпраці, відповідальність за спільний результат, повага до інших.

Особливу роль відіграє парна взаємодія, яка вимагає узгодженості дій, взаєморозуміння та довіри. Це сприяє розвитку соціального інтелекту.

З позицій соціального навчання, діти засвоюють моделі поведінки через наслідування. У танцювальному колективі вони переймають норми поведінки, культуру спілкування та етичні цінності.

Таким чином, бальний танець виступає ефективним засобом соціалізації дітей дошкільного віку.

Естетичний розвиток є важливою складовою формування гармонійної особистості. Бальний танець, як вид мистецтва, має значний потенціал у цьому напрямі.

Естетичне виховання у процесі танцю включає:

- формування відчуття краси руху;
- розвиток художнього смаку;
- здатність до сприйняття та створення образів;
- розвиток творчої уяви.

Згідно з культурологічним підходом, мистецтво є засобом передачі культурних цінностей. Через танець дитина долучається до культурної спадщини, засвоює норми естетичної поведінки.

Танцювальна діяльність сприяє розвитку образного мислення, що є основою творчості. Дитина не лише відтворює рухи, а й наповнює їх емоційним змістом, створюючи власний художній образ.

Таким чином, бальний танець виступає ефективним засобом формування естетичної культури особистості.

Педагогічні особливості навчання дітей 3–6 років

Дошкільний вік (3–6 років) є сенситивним періодом розвитку дитини, упродовж якого відбувається інтенсивне становлення фізичних, психічних і соціальних функцій. Саме в цей період закладаються основи майбутньої особистості, формуються базові рухові навички, розвивається емоційна сфера, мовлення, мислення та уява.

Згідно з положеннями вікової психології (Л. Виготський, О. Леонтьєв, Д. Ельконін), провідною діяльністю у дошкільному віці є гра, яка виступає основним механізмом розвитку дитини. Саме через ігрову діяльність відбувається засвоєння соціальних ролей, норм поведінки та способів взаємодії з оточенням.

У контексті навчання бальним танцям це означає, що освітній процес має бути організований із урахуванням таких принципів:

Принцип ігрової діяльності

Гра є природною формою активності дитини, тому навчання повинно відбуватися через ігрові ситуації, сюжетні образи та емоційно насичені завдання. Використання ігрових методів сприяє:

підвищенню мотивації до занять;

зниженню психоемоційного напруження;

активізації пізнавальної діяльності.

У танцювальній практиці це реалізується через використання ігор-імітацій, сюжетних танців, рухових фантазій.

Принцип наочності та наслідування

Діти дошкільного віку характеризуються високим рівнем наслідувальної діяльності. Вони засвоюють нові рухи переважно через спостереження та повторення.

Згідно з теорією соціального навчання, наслідування є ключовим механізмом формування поведінки. Тому педагог у процесі навчання виступає як зразок, модель для відтворення.

Ефективність навчання значно підвищується за умови:

- чіткого показу рухів;
- використання дзеркального методу;
- поетапного розучування елементів.

Принцип доступності та індивідуалізації

У дошкільному віці спостерігаються значні індивідуальні відмінності у темпах розвитку дітей. Це зумовлює необхідність диференційованого підходу до навчання.

Принцип доступності передбачає:

відповідність навчального матеріалу віковим можливостям;

поступове ускладнення завдань;

врахування рівня підготовки кожної дитини.

Індивідуалізація навчання сприяє створенню ситуації успіху, що є важливим фактором формування позитивної мотивації.

Принцип емоційної насиченості

Емоційний компонент відіграє провідну роль у навчанні дітей дошкільного віку. Як зазначав Л. Виготський, навчання є ефективним лише тоді, коли воно викликає емоційний відгук у дитини.

Танцювальна діяльність за своєю природою є емоційно насиченою, що забезпечує:

глибше засвоєння матеріалу;

формування позитивного ставлення до занять;

розвиток емоційної сфери.

Педагог має активно використовувати:

образні порівняння;

емоційно виразну музику;

підтримку та заохочення.

Принцип рухової активності та варіативності

Діти 3–6 років мають обмежену здатність до тривалої концентрації уваги. Тому важливо забезпечити постійну зміну видів діяльності.

Заняття повинно включати:

- чергування активних і спокійних вправ;
- зміну темпу та характеру рухів;
- поєднання навчальних і ігрових елементів.

Це дозволяє підтримувати інтерес і запобігати перевтомі.

Принцип розвитку зони найближчого розвитку

Відповідно до концепції Л. Виготського, навчання має випереджати розвиток і орієнтуватися на зону найближчого розвитку дитини.

Це означає, що педагог повинен пропонувати завдання, які:

- є дещо складнішими за наявний рівень умінь;
- можуть бути виконані за підтримки дорослого;
- стимулюють розвиток нових навичок.

У танцювальній діяльності це реалізується через поступове ускладнення рухів, введення нових елементів і комбінацій.

Важливим компонентом успішного навчання є взаємодія з батьками. У дошкільному віці саме батьки формують мотивацію дитини до занять.

Педагогічна практика свідчить, що ефективність навчання значно зростає за умов:

- позитивного ставлення батьків до занять;
- їхньої участі у підготовці дитини;

- підтримки та заохочення.

Мотивація, сформована в сім'ї, виступає важливим чинником стабільності навчального процесу.

Діти дошкільного віку засвоюють рухи переважно на рівні цілісного сприйняття, а не через аналітичне розчленування. Тому навчання має будуватися за принципом:

«від простого до складного»;

«від цілого до частин»;

«через повторення до автоматизації».

Регулярність і систематичність занять забезпечують формування стійких рухових навичок.

Таким чином, педагогічні особливості навчання дітей 3–6 років визначаються їхніми віковими психофізіологічними характеристиками. Ефективна організація занять з бального танцю можлива лише за умови врахування принципів ігрової діяльності, емоційної насиченості, доступності, індивідуалізації та розвитку.

Дотримання цих принципів забезпечує не лише успішне засвоєння танцювальних навичок, а й гармонійний розвиток особистості дитини.

Таблиця 1

Методична модель заняття з бального танцю для дітей дошкільного віку

Етап	Зміст	Педагогічна мета	Методичні прийоми
Вступний	Привітання, налаштування	Емоційна адаптація	ігрові ритуали
Розминка	Загальні вправи	Підготовка організму	рухи під музику
Основна частина	Вивчення рухів	Формування навичок	показ, повтор
Ігровий блок	Танцювальні ігри	Розвиток творчості	імпровізація
Завершення	Релаксація	Відновлення	дихальні вправи

Таким чином можемо зазначити, що бальний танець є ефективним засобом всебічного розвитку дитини. Він забезпечує гармонійне поєднання фізичного, психоемоційного та естетичного розвитку.

Раннє залучення дітей до танцювальної діяльності сприяє формуванню здорової, творчої та соціально активної особистості.

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SECTION OF MATHEMATICS, PHYSICS, AND INFORMATICS

РОЗРОБКА МЕТОДІВ ВИСОКОПРОДУКТИВНОЇ ТАБЛИЧНОЇ ОБРОБКИ ІНФОРМАЦІЇ В СПЕЦІАЛІЗОВАНИХ КОМП'ЮТЕРНИХ ЗАСОБАХ НА ОСНОВІ СИСТЕМИ ЗАЛИШКОВИХ КЛАСІВ

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DEVELOPMENT OF METHODS FOR HIGH-PERFORMANCE TABULAR INFORMATION PROCESSING IN SPECIALIZED COMPUTER TOOLS BASED ON THE RESIDUE NUMBER SYSTEM

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Анотація

У статті розглядаються науково-технічні засади створення високопродуктивних спеціалізованих комп'ютерних засобів обробки інформації (СКЗОІ) на основі непозиційної системи числення, а саме системи залишкових класів (СЗК). Обґрунтовано актуальність застосування табличної арифметики для реалізації модульних операцій у реальному часі. Розроблено вдосконалену математичну модель процесу табличної реалізації операції алгебраїчного множення, що базується на використанні коду інформаційного стиснення даних (КІСД). Запропонована модель враховує специфіку обробки даних як для парних, так і для непарних основ СЗК, що дозволяє суттєво (на 50–70%) скоротити обсяг апаратних витрат постійних запам'ятовувальних пристроїв (ПЗП). Результати дослідження спрямовані на підвищення швидкодії та надійності функціонування СКЗОІ в задачах криптографічного захисту та цифрової обробки сигналів.

Abstract

The article considers the scientific and technical principles of creating high-performance specialized computer information processing tools (SCIP) based on a non-positional residue number system (RNS). The relevance of using tabular arithmetic for the implementation of modular operations in real time is substantiated. An improved mathematical model of the process of tabular implementation of the algebraic multiplication operation is developed, based on the use of data information compression code (DICC). The proposed model takes into account the specifics of data processing for both even and odd RNS bases, which allows significantly (by 50-70%) reducing the hardware costs of read-only memory (ROM). The research results are aimed at increasing the speed and reliability of SCIP in cryptographic protection and digital signal processing tasks.

Ключові слова: спеціалізовані комп'ютерні засоби, система залишкових класів, таблична арифметика, алгебраїчне множення, код інформаційного стиснення даних.

Keywords: specialized computer tools, residue number system, tabular arithmetic, algebraic multiplication, data information compression code.

Introduction. The current stage of information technology development is characterized by a rapid increase in the volume of data requiring real-time processing. The scale and complexity of tasks solved by modern specialized computer information processing tools (SCIPT) impose qualitatively new requirements on their performance, reliability, and energy efficiency [8, p. 112]. This issue is particularly acute for mission-critical systems: cryptographic information protection (specifically the implementation of asymmetric algorithms based on elliptic curves), digital signal processing in radar, and the control of autonomous robotic platforms.

Problem Statement. Traditional computing structures based on positional numbering systems (PNS) have practically exhausted their potential for extensive development. The main obstacle is the presence of sequential inter-bit connections (carries), which limit the maximum clock frequency of processors [2, p. 24]. As the bit depth of operands increases—which is critical for modern cryptography, where key lengths reach 256–512 bits and more—the execution time of arithmetic operations increases linearly or exponentially. This directly contradicts the requirements of real-time operation. Attempts to solve this problem through simple parallelization within the PNS lead to excessive complexity of hardware logic and a critical increase in power consumption. As noted in classical studies on parallel systems, performance instrumentation remains a critical bottleneck when dealing with high-precision

arithmetic [6, p. 465]. Thus, a scientific contradiction arises between the need for ultra-high speed and the physical limitations of positional arithmetic.

An alternative and promising way to solve this problem is the transition to a non-positional residue number system (RNS). RNS allows transforming a complex operation on large numbers into a series of parallel operations on low-bit residues [7, p. 2]. The most effective method for implementing such operations is tabular arithmetic, which allows obtaining a result in a single clock cycle but requires the development of new data compression methods to optimize ROM memory capacity.

Relevance of the research. The relevance is driven by the need to develop methods for increasing information processing productivity without compromising the functional reliability of SCIPT. The application of RNS in modular arithmetic allows for significant optimization of the bit grid, especially in preventing overflow during intensive calculations [5, p. 230]. Traditional PNS, when implementing the tabular method, require an excessive amount of hardware: for an *l*-byte operational unit, the number of logic gates is $N_l = 2^{16l}$. Already at *l*=4, this value reaches 2^{64}, making the tabular method in PNS practically inapplicable.

In contrast, in RNS for *l*=4, the number of gates is only 2397, which is highly acceptable for modern hardware components (FPGA, ASIC). Therefore, the development of specialized tools based on RNS is a fundamental alternative for creating high-performance real-time computing systems.

Modern research in neurocomputer structures further confirms that RNS-based arithmetic significantly enhances the speed of specialized neural processors [3, p. 85].

Mathematical modeling of tabular algebraic multiplication. To construct a mathematical model (MM) of the tabular multiplication process in RNS for both positive and negative ranges, input numbers *A* and *B* are represented in an artificial form. This modeling is fundamental for the implementation of cryptographic transformations, where digital security relies on the high-speed execution of modular operations [4, p. 58]. If the modulus *m* is an even number, the following relations hold:

$$A = \bar{a} - z_a \cdot \frac{m}{2},$$
$$B = \bar{b} - z_b \cdot \frac{m}{2},$$

where $\bar{a}, \bar{b}$ represent the numerical part, and z_a, z_b represent the data information compression code (DICC) attribute.

The product $A \cdot B(mod\, m)$ for even moduli is described by the formula:

$$A \cdot B(mod\, m) = \left| \bar{a} \cdot \bar{b} - \frac{m}{2}(z_a \cdot \bar{b} + z_b \cdot \bar{a}) + z_a \cdot z_b \frac{m^2}{4} \right| (mod\, m).$$

Considering that the term $\frac{m^2}{4}$ may introduce a calculation error, the final model for an even modulus is:

$$A \cdot B(mod\, m) = \left| \bar{a} \cdot \bar{b} - \frac{m}{2}(z_a \cdot \bar{b} + z_b \cdot \bar{a}) \right| (mod\, m), \text{ if } z_a \cdot z_b = 0,$$

or

$$A \cdot B(mod\, m) = \left| \bar{a} \cdot \bar{b} - \frac{m}{2}(z_a \cdot \bar{b} + z_b \cdot \bar{a} - 1) \right| (mod\, m), \text{ if } z_a \cdot z_b = 1.$$

For odd moduli (which constitute the majority of bases in RNS), the formula is transformed considering integer division:

$$A \cdot B(mod\, m) = \left| \bar{a} \cdot \bar{b} - \frac{m-1}{2}(z_a \cdot \bar{b} + z_b \cdot \bar{a}) + z_a \cdot z_b \frac{m-1}{4} \right| (mod\, m).$$

The DICC attribute of the result z_c the product table of an arbitrary modulus *m* is determined by the logical XOR sum of the input attributes and the internal product attribute z_{prod}:

for even *m*: $z_c = (z_a \oplus z_b) \oplus z_{prod}$;

for odd *m*: $z_c = z_a \oplus z_b$ (with respective correction logic),

where $(z_a \oplus z_b)$ represents the preliminary determination of the result's range based on the input operands' quadrants. This functions as a modular parity check, similar to the sign rule in traditional arithmetic.

z_{prod} is the internal attribute stored within the optimized ROM. Since the multiplication of numerical parts $\bar{a} \cdot \bar{b}(mod\, m)$ can itself cross the $\frac{m}{2}$ boundary, z_{prod} acts as a correction factor derived from the symmetry of the modular multiplication table.

This logic ensures the correct mapping of the modular product back into the full range of the residue class, which is a critical step in maintaining data integrity during non-positional code transformations [9, p. 52]. Furthermore, such algebraic properties are foundational for advanced logarithmic number systems used in specialized implementations [1, p. 198].

Optimization of operational unit structure. The proposed implementation of modular operations in RNS optimizes the SCIPT structure by utilizing the symmetry properties of ROM tables. The table of values $C = (a_i \cdot b_i)\, mod\, m$ is symmetric relative to the diagonals, vertical, and horizontal axes. Using DICC allows:

- Reduction of ROM table volume by 4 times by storing only one quadrant.
- Increased reliability and reduced recovery time due to the modular principle of the processing tract.
- Reduced power consumption, which is critical for autonomous robotic platforms and mobile cryptographic devices.

Conclusion. The developed mathematical model for the tabular implementation of algebraic multiplication in RNS provides a robust framework for creating high-efficiency arithmetic-logic units. Reducing ROM hardware requirements by 50–70% while ensuring sin-

gle-clock cycle execution confirms the feasibility of integrating these methods into specialized SCIPT. This research establishes a solid theoretical foundation for further dissertation work in the field of high-performance specialized computer systems.

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SECTION OF SOCIAL AND ECONOMIC SCIENCES

HUMAN CAPITAL AND DIGITAL INFRASTRUCTURE AS DETERMINANTS OF UNEVEN KNOWLEDGE ECONOMY FORMATION IN UKRAINIAN REGIONS

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Abstract
The article investigates human capital and digital infrastructure as key determinants of uneven knowledge economy formation in Ukrainian regions. Mechanisms of interdependence between human resources qualification and regional digital environment are revealed. A typology of Ukrainian regions by levels of human capital and digital infrastructure development is constructed. Persistent regional disparities and their structural and situational drivers — including the destructive impact of armed aggression — are identified. A set of differentiated regional policy measures aimed at overcoming these disparities is proposed.
Keywords: human capital, digital infrastructure, knowledge economy, regional development, digital divide, regional disparities, digital transformation.

INTRODUCTION

Spatial unevenness of development is one of the fundamental regularities of the market economy. In the context of the transition to a knowledge economy, this unevenness acquires new dimensions and reproduction mechanisms. If in the industrial era regional disparities were determined by the availability of natural resources and transport accessibility, then in post-industrial conditions human capital and digital infrastructure become the leading factors of regional differentiation [7].

For Ukraine, the problem of regional differences in human capital development and digital infrastructure is particularly acute: the country entered the phase of digital transformation with significant structural imbalances between regions, inherited from the Soviet past and deepened during the years of independence. Russia's armed aggression after 2022 inflicted additional, asymmetric blows on regional human capital systems and digital infrastructure, exacerbating an already complex situation [2; 14].

The aim of the article is to investigate human capital and digital infrastructure as determinants of uneven knowledge economy formation in Ukrainian regions, to identify spatial patterns and factors of regional differentiation, and to substantiate measures of corresponding regional policy.

The object of the study is the regional systems of human capital and digital infrastructure of Ukraine; the subject is the patterns and mechanisms of their impact on the unevenness of regional knowledge economy formation.

The methodological basis of the study comprises comparative analysis, typologization, the cartographic method and statistical analysis methods. The information base consists of data from the State Statistics Service of Ukraine, reports of the Ministry of Digital Transformation [6], OECD and World Bank materials [9; 10; 17], as well as research results of domestic and foreign scholars.

1. Human capital as a determinant of regional knowledge economy: theoretical foundations and measurements

The concept of human capital developed by G. Becker [1] and T. Schultz [13] gained a new dimension in the theory of the knowledge economy: knowledge and competencies were transformed from one of the components of human capital into its central element. R. Lucas [4] and P. Romer [12] theoretically substantiated that the accumulation of human capital is the driver of endogenous economic growth and generates external effects (externalities) that are amplified in spatial clusters.

In the regional dimension, the quality of human capital is determined by the interaction of several factors: the educational level of the population, the employment structure, the concentration of research personnel, the mobility of qualified specialists and their opportunities for lifelong learning. For the regional knowledge economy, what matters is not simply the availability of highly qualified personnel, but their retention in the region and productive engagement in knowledge-innovation processes [2; 16].

A significant methodological challenge is the complexity of measuring human capital at the regional level. The most commonly used indicators are: the share of population with higher education, the number of researchers per 1,000 employed, expenditures on education and training (relative to GRP), and human development indices. Each of these indicators reflects only a single dimension and does not provide a complete picture of regional human capital. This article proposes an aggregated assessment based on a combination of four indicators (Table 1).

Table 1

Comparative indicators of human capital and digital readiness of Ukrainian regions (author's calculations based on State Statistics Service and Ministry of Digital Transformation data, 2021–2022)

Region type	Share of employed with higher education, %	Researchers per 1,000 employed	Digital Readiness Index (0–1)	IT company density (per 10,000 pop.)
Knowledge Leaders (Kyiv, Lviv, Dnipro)	42–48	8.2–12.1	0.68–0.82	9.4–14.2
Potential Leaders (Odesa, Vinnytsia, Poltava)	32–38	4.1–6.8	0.45–0.62	3.8–6.1
Digital Outsiders (Kirovohrad, Rivne, Volyn, etc.)	24–30	1.8–3.2	0.28–0.41	0.9–2.3
Militarily destructured (Donetsk, Luhansk, Zaporizhzhia, etc.)	n/a	n/a	disrupted	disrupted

** Data prior to the full-scale invasion; 2023–2024 statistics are incomplete due to hostilities.*

The data in Table 1 clearly demonstrate a significant gap between leading and peripheral regions. The gap in the share of employed with higher education between Kyiv and agrarian regions reaches 2.1 times, while for the digital readiness index it is 2.5 times. These figures indicate that the digital divide amplifies and reproduces the unevenness of human capital, forming a closed loop of regional polarization [11].

2. Digital infrastructure as a spatial factor of the knowledge economy

Digital infrastructure is a necessary environment for the functioning of the knowledge economy: it provides access to information, enables distance education and work, reduces transaction costs of knowledge exchange, and creates conditions for the development of the IT industry and digital services [3; 9]. In the regional dimension, digital infrastructure plays the role of a "spatial equalizer" — it is potentially capable of reducing the significance of geographic peripherality and bringing remote regions closer to knowledge generation centres.

However, empirical data show that this equalizing potential is far from being realized automatically. Studies of the effects of broadband internet access in various countries show that access to the network alone increases rather than decreases regional inequality if it is not accompanied by adequate human capital and an institutional environment [5; 11]. In other words, digital infrastructure is a necessary but not sufficient condition: its effectiveness for the formation of regional knowledge economy depends on the ability of the population and economic entities to use it.

Table 2

Disparities in digital infrastructure development between urban and peripheral regions of Ukraine

Indicator	Kyiv	Kharkiv	Lviv	Agrarian periphery (average)
Broadband internet penetration, %	89	78	74	41–52
4G/LTE mobile network coverage, %	96	89	87	55–68
Share of e-services users, %	67	54	59	22–34
IT company density (per 10,000 pop.)	14.2	11.8	10.3	0.9–2.3
Average Internet speed, Mbps	82	61	68	18–28

The data in Table 2 confirm significant disparities in digital infrastructure development. Particularly striking is the gap in IT company density — almost an order of magnitude greater in leading cities compared to peripheral regions. This explains the concentration of the IT industry — one of the key sectors of the knowledge economy — in several large cities (Kyiv, Kharkiv, Lviv, Dnipro, Odesa), which was observed before the full-scale invasion [6; 15].

Fundamentally important is also the issue of qualitative differentiation of digital infrastructure: not merely the availability of internet connection, but speed, reliability, cybersecurity, accessibility of cloud services and data centres. By these parameters, the regional gap is even greater than for basic access [9].

3. Interaction of human capital and digital infrastructure in the formation of regional knowledge systems

Human capital and digital infrastructure are not independent determinants of the regional knowledge economy: they are in a relationship of complementarity and mutual reinforcement. On the one hand, developed digital infrastructure increases the productivity of human capital, expands access to education and knowledge, and opens new employment opportunities in knowledge-intensive sectors. On the other hand, the

mere availability of digital infrastructure is insufficient without human capital capable of using it effectively.

This complementarity generates the "cumulative causation effect" (G. Myrdal [8]): regions with developed human capital and digital infrastructure attract additional investment, qualified migrants and new businesses, which further strengthens their positions. In contrast, lagging regions face the outflow of qualified personnel and reduced investment, which consolidates their peripheral status. Thus, without active regional and national policy intervention, market mechanisms amplify rather than overcome the uneven formation of the knowledge economy [11; 18].

The situation in Ukraine after 2022 has become significantly more complex: the full-scale armed aggression dealt an asymmetric blow to the regional systems of human capital and digital infrastructure. Regions with significant human capital (Kharkiv, Zaporizhzhia, Donetsk, Kherson, Luhansk, Mykolaiv, Sumy, Chernihiv oblasts) suffered the greatest losses due to hostilities, evacuation of the population and destruction of infrastructure, and their knowledge potential relocated either to safer Ukrainian regions or abroad [2; 14].

4. Typology of Ukrainian regions by human capital and digital infrastructure development

Based on the analysis performed, a typology of Ukrainian regions is proposed according to the combination of development levels of human capital (HC) and digital infrastructure (DI):

Type 1. "Knowledge Leaders" (high HC + high DI): Kyiv city, Kharkiv (before 2022), Lviv, Dnipropetrovsk oblasts. These regions are characterized by the concentration of universities, scientific institutions, IT companies and qualified specialists. They are the nuclei of regional innovation systems and form "attraction points" for human capital [7; 16].

Type 2. "Potential Leaders" (medium HC + medium/high DI): Odesa, Zaporizhzhia (before 2022), Vinnytsia, Poltava oblasts. These regions have the necessary foundation for knowledge economy development but have not yet realized their potential due to institutional and structural constraints [11].

Type 3. "Digital Outsiders" (low HC + low DI): A significant part of agrarian oblasts — Kirovohrad, Cherkasy, Ternopil, Rivne, Volyn, Chernivtsi oblasts. These are characterized by human capital outflow, weak digital infrastructure and the dominance of low-technology sectors [18].

Type 4. "Militarily Destructured" (disrupted HC + destroyed DI): Donetsk, Luhansk, Zaporizhzhia, Kherson, Mykolaiv, partially Kharkiv, Sumy, Chernihiv oblasts. This typological group is specifically Ukrainian and has no analogues in foreign classifications [2; 14].

The proposed typology allows for the differentiation of regional policy measures depending on the combination of human capital and digital infrastructure development levels, avoiding template approaches that are identical for fundamentally different regional situations.

5. Directions of regional policy for eliminating disparities

The identified patterns allow us to substantiate the principles and specific instruments of regional policy aimed at overcoming disparities in human capital and digital infrastructure development:

The first principle is differentiation: measures should correspond to the type of region (according to the proposed typology), rather than being uniform for the entire country. For "knowledge leaders", relevant measures include talent retention and scaling of innovation ecosystems; for "digital outsiders" — basic digitalization and educational programs; for "militarily destructured" regions — infrastructure restoration and the return of evacuated human capital [2; 10].

The second principle is complementarity of investments: investments in digital infrastructure must necessarily be accompanied by digital literacy programs and skills development, otherwise their effect for the knowledge economy will remain minimal. Isolated investments in "hardware" without the corresponding "human" component are ineffective [10; 11].

The third principle is resilience: in the context of wartime and post-war conditions, the capacity of regional knowledge systems to maintain functioning and recover from destructive shocks becomes critically important. This requires the decentralization of critical digital infrastructure nodes, the formation of reserve capacities, and mechanisms for preserving and returning human capital [2; 15].

Conclusion

Human capital and digital infrastructure are interrelated and mutually reinforcing determinants of the regional knowledge economy. Their complementary nature determines the effect of cumulative amplification of regional disparities: successful regions increase their advantages, while lagging ones consolidate their weaknesses.

In Ukraine, these disparities have a dual character: on one hand, they are a structural legacy of the past (concentration of scientific and educational institutions in a few large cities), and on the other — they acquired new manifestations as a result of armed aggression, which asymmetrically struck regions with significant knowledge potential [2; 14].

The proposed typology of regions and the substantiated principles of regional policy create a practical foundation for differentiated, complementary and resilient approaches to supporting human capital and digital infrastructure development in different types of Ukrainian regions [10; 18].

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